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ABSTRACT

Teachers in England and Wales are working to implement the targets and programs of study for technology, which was defined in the 1993 National Curriculum as "the creative application of knowledge, skills, and understanding to design and make good quality products." To determine the needs and attitudes of primary-school staff, researchers conducted a study in 12 primary schools. The researcher observed teachers and students in four classrooms as the students engaged in design and technology activities, recording children's responses to these tasks using video recording, photographs, field notes, and interviews with the children. (Two such activities consisted of making models of vehicles used on a building site and a traction engine by 6- and 7-year-old children.) Interviews and observations show that teachers were left to operationalize the order for technology use through trial and error, and that many lacked the necessary technical and conceptual knowledge and craft skills. Issues about teaching technological capability that were identified by this study include: (1) communicating through drawing; (2) acquiring technical skills; (3) acquiring technical knowledge; and (4) providing opportunities for students to evaluate "real" artifacts using predetermined criteria. It is concluded that, while many areas of design and technology capability remain under-researched, the four issues listed will be the focus of additional study. Ten figures illustrate the discussion. (Contains 24 references.) (SLD)

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# TECHNOLOGICAL CAPABILITY IN THE PRIMARY SCHOOL CLASSROOM

A J E Anning

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## INTRODUCTION

The National Curriculum Council for England and Wales recommendations for the revised attainment targets and programmes of study for technology were published in September 1993 (National Curriculum Council, 1993). In 1993 responsibility for the National Curriculum became the remit of the newly wedded National Curriculum Council (NCC) and Schools Examinations and Assessment Council (SEAC), now jointly known as the School Curriculum and Assessment Authority (SCAA). It is intended that a new order for Key Stages 1, 2 and 3 (KSs), Technology will be implemented in September 1995.

In the 1993 recommendations Technology is newly defined as 'the creative application of knowledge, skills and understanding to design and make good quality products'. The Programmes of study have been reduced and simplified. Attainment Targets have been reduced to Designing (AT1) and Making (AT2). Pupils should undertake two assignments at KS1 and four at KS2 'in which pupils design and make products with a clear purpose'. It is recommended that Information Technology, now defined as a new basic skill, should be reported upon separately from Design and Technology.

But Primary school teachers are still struggling to come to terms with the original 1990 Technology Order and will be expected to do so until September 1995. What understanding do primary school teachers have of Technology currently? What are their expectations and understanding of young children's capability in technology? There has been a smattering of small scale research studies into how the 1990 Technology order has been operationalised in primary classrooms (Johnsey 1993, Anning 1993), evidence from Her Majesty's Inspectorate (HMI), (DES 1991, 1992) and some innovative work from the Consortium for Assessment in Technology (CATS) team on assessment of children's capability in technology at KS1 (SEAC, 1992, CATS 1992, Kimbell et al 1991). However our research base in England and Wales in teaching and learning technology at KS 1 and 2 is pitifully inadequate. There is an urgent need to research into teaching and learning technology at ages 5 to 11 so that we may understand how to help primary teachers to operationalise the revised Order in 1995 in a more productive way.

### Methodology

This paper is based on analysis of interviews with the staff of twelve primary schools, six in each of two LEAs and detailed observations of children working in four classrooms - two Year 1 and two Year 3 classes - as primary teachers struggled to implement the 1990 Technology Order.

The schools were identified by Local Authority Primary Advisers as having a positive commitment to implementing the Order. In each of the twelve schools half-hour structured interviews with the headteacher, co-ordinator for Technology and the class teachers responsible for introducing the Order at the beginning of each Key stage (Years 1 and 3) were tape recorded and transcribed. The interviews addressed their attitude towards implementing the Order, their understanding of its content, their response to the idea of progression implicit in the statements of Attainment, their concerns about operationalising the Order, what resources they had or intended to purchase, what classroom organisation strategies they believed to be appropriate for teaching and learning technology, and what previous experience they and their pupils had of teaching and learning technology.

Four of the class teachers agreed to cooperate with the researcher in explaining their plans to implement the order in their classrooms. The researcher spent two separate weeks in the Autumn term of 1990 and the Summer term of 1991 observing in the four classrooms. She talked with the teachers about

tasks they defined as Design and Technology activities. She recorded the children's responses to these tasks using video recording, photographs, field notes and interviews with the children. The interviews explored their thinking about their intentions, the way they worked and their achievements. The combination of video recordings, tape recordings, field notes and photographs of children's work provided a rich source of detailed information about what teachers and children were actually doing in 'Technology' activities.

Discussion of the data raises issues about how both teachers and children in primary school classrooms are interpreting the legal requirements of the current Order into activities defined as Design and Technology.

## CAPABILITY IN CONTEXT

When the original Technology Order landed on the staffroom tables of primary schools in the Summer of 1990, teachers were already reeling under the strain of implementing the English, Maths and Science Orders. For a largely Arts/Humanities educated and female workforce the Technology Order was inaccessible and alienating. The language intimitated them. A teacher said:

> "We just didn't understand the language of the document. It was on about generating or whatever it was - that sort of thing and the images of generating or something - that was when we really started panicking."

There was also the conceptual difficulty of coming to terms with the innovative model of design and technology capability embedded in the four attainment targets - Identifying Needs and Opportunities, Generating a Design, Planning and Making, and Evaluating - conceived as domains of an iterative and holistic process, leading to design and technology capability. A teacher admitted:

> "I find it very difficult. I've read it two or three times and I can't hold it all in my head. It's so fine and the terms are foreign to me. I keep reading it and going back to it, and it's the fact that you can't dip, which I think you can do with the other documents - that you have to hold on to the whole thing and understand the whole thing."

The teachers to whom we spoke recognised clearly that, despite their efforts at 'self-help' during school based training days and LEA in-service courses designed to support them, they were lacking in the confidence and the technical and conceptual knowledge and craft skills they needed to implement the order. Interviews we did with teachers in two LEAs reflected the depressingly low figure of one in seven of a national sample of primary teachers surveyed in a Leverhulme Project (Wragg, 1989) who felt competent to teach technology.

Despite the rhetoric that primary teachers value practical work, research demonstrates consistently that teachers devote two-thirds of their time to working with children involved in seat-based basic skills (numeracy and literacy) activities and little time interacting with children engaged on practical tasks, with the exception of science and maths ( Tizard et al, 1988; DES, 1991; Alexander et al, 1992). In the workshop areas where art, craft, role play, construction play, and technological activities are sited, the most common pattern is for activities to be set up by the teacher at the start of the day, with brief verbal instructions delivered to the whole class about what is expected of them and perhaps reference to the way tools should be handled and what materials might be used. For the rest of the day the activities are sustained by groups of children working independently of the teacher. The teacher makes sporadic visits to the areas - often in a trouble shooting capacity - but rarely observes the processes by which the children work sequentially through the tasks. A non-teaching assistant or parent may be assigned to monitor the activities, but as Bennett and Kell (1989) reported, these adults are rarely briefed adequately by the teacher as to the purpose of the tasks. It is not surprising then that primary teachers

have a limited understanding of how children make progress in and through practical work. Nor is it surprising that faced with uncertainties about how to implement the Technology Order, primary teachers fell back on their knowledge of teaching and learning in art, craft and design, environmental studies and structured play. A Key Stage 1 teacher said:

> "It's more or less what we've been doing all along. We have always done such things as turning the house corner into a shop or something like that, and I think if we carry on doing them we are covering practically everything that is in the document. It's just got a new label, hasn't it? That's basically it."

More defiantly, a headteacher said:

> "When this magical thing called Technology was discovered - I don't know who it was decided to discover it (whether it was Mr Baker or somebody else) - we assessed what technology really included. And basically it's all the art work, the physical side of the art work - I don't mean the brain side of it, that probably comes from design somehow. All the baking, all the cooking, the clay work, the box work, the book making, and woodwork - and certainly doesn't the maths come into technology and technology into maths - and science? It virtually covered everything and as we do a lot of topic based work, technology could be said to be in everything. We just fill in that silly purple form (the DFE curriculum audit form) and really you know technology could be counted up as 100%!"

These quotations demonstrate the kind of strategies practitioners use in order to cope with change imposed upon them from above. As Jean Ruddock has written:

> 'The inertia of past meanings is a formidable barrier to change. In education, you cannot create a vacuum in which to grow a new set of meanings and practices; you cannot stop teaching for a year in order to work in a different way. The show must go on. It is against such pressures that the task of change has to be undertaken' (Rudduck, 1986)

The distinction that the primary headteacher quoted drew between the 'physical side of the art work' and 'the brain side of it' is an interesting one, and points to another contextual feature of technological capability in primary schools - the models of the learning process held by teachers and the pedagogical implications of their beliefs for their practice in classrooms. For example in primary schools, children's learning in the visual arts and crafts is rarely systematically supported by direct instruction. Teachers uphold a 'laissez faire' tradition, embedded in notions of 'child-centredness', of children being allowed to be creative without adult interference. In science, on the other hand, direct instruction and careful supervision of practical work is seen as appropriate. The concept of Design and Technology, defined by the working group as a 'unitary concept, to be spoken in one breath as it were' (DES, 1989, 1.6), allows the subject to sit uneasily between the two very different conceptual and pedagogic traditions of the arts (Design) and sciences (Technology). The original draft Orders for Technology for KS1 and 2 were in fact 'attached' to the draft Science Order (DES/WO 1988)) and many local authority primary science advisers and staff in Higher Education with responsibility for providing initial and inservice primary science education added Technology to their science curriculum training roles.

In the two LEAs in which we observed strategic models of technology education, the Order was interpreted very differently. The messages disseminated through in-service courses reflected the value systems of advisers with responsibility for technology employed by LEAs, and such macro-level belief systems had implications for the ways in which technology education was operationalised in the schools and classrooms where we observed.

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## CAPABILITY IN ACTION

What then did operationalised versions of the Order look like? The two exemplars below give a flavour of the kind of activities that two teachers in two different LEAs defined as design and technology.

### Examplar 1

Key Stage 1, Making Models of Vehicles used on a Building Site (Ryan age 6.9, John age 6.9, Rebecca age 6.8, Diane age 6.6)

The advisory teacher providing support for the primary schools in this area had a secondary school technology background. His emphasis on in-service courses tended to be on the technical knowledge underpinning model making - how to make axles, pulley systems, gears and levers etc. However, the LEA in-service provision also had a history of promoting quality in the visual arts and craft skills as in the former West Riding tradition, of whom the best known figurehead was Sir Alec Clegg.

The classroom in which we observed was in a small village school (total pupil numbers 75) with a mixed age range of five to seven year olds. The organisation was group work, with some element of choice for children each day. The advisory teacher had instructed the children on how to make a chassis with axles using a system of wooden spring pegs glued to a piece of thick card, with dowelling pushed through the holes in the peg handles and wooden wheels attached. Later in the week a non-teaching assistant helped the children to make their own chasses. The researcher's field notes indicate the difficulties that the six year olds were having in handling the equipment and materials, despite the previous instruction from an 'expert' and the guidance of an adult.

> 'They began by positioning the pegs - had to put them in exactly the same positions as on the prototype from yesterday's input - was not sure if they understood that the really important point was to align the holes of the pegs to slot the axles through. Expert application of glue - lots of previous experience? Sawing dowel - when marking lengths children told to measure exactly between two points, but forgetting to add overlap for wheel attachments. Positioning of bench hooks often wrong - not hooked over table top edge. Better if they'd been clamped to table? Very hard for the children to saw the circular dowel - hard to grip with one hand, hard wood, slippery, flailed about. Difficulty in knowing where to position wood and saw - which hand to use for what'

The second stage of the task was for the children to make a model of a vehicle that would be useful on a building site. The worktable was resourced with two picture books of earth moving equipment which had been a stimulus for discussion in the introductory class session, though none of the children were observed using them for reference.

Ryan (age 6.9) was first to finish making his chassis. The non-teaching assistant demonstrated how he could use two pegs and an axle as the pivot for the lifting arm of a digger. He was dissuaded from using a bent straw for the arm of the contraption - 'not strong enough to lift anything'. He used a strip of corrugated card with the dowel pushed through one of the ridges. He glued a cut down polystyrene cup to the end of the arm for the scoop. He then attached the top half of an eggbox to the chassis for a container. A piece of string was tied loosely around the arm to lift the scoop. He spent a long time, with adult suggestions at various points, experimenting to find a way of making a winding mechanism. He knew that it needed a cylindrical drum and tried out a yoghurt pot, first upright, then inverted, and then a cotton reel. He used the holes in the side of an eggbox container to thread the string along to the end of the chassis, but when the angle was not right for lifting the arm, punched a hole in the chassis itself. He abandoned his attempts to make a winder. See Figure 1.

Figure 1 Ryan working on a winding mechanism.

Figure 2 Rebecca's double action scoop

9

**Figure 3 The four completed models**

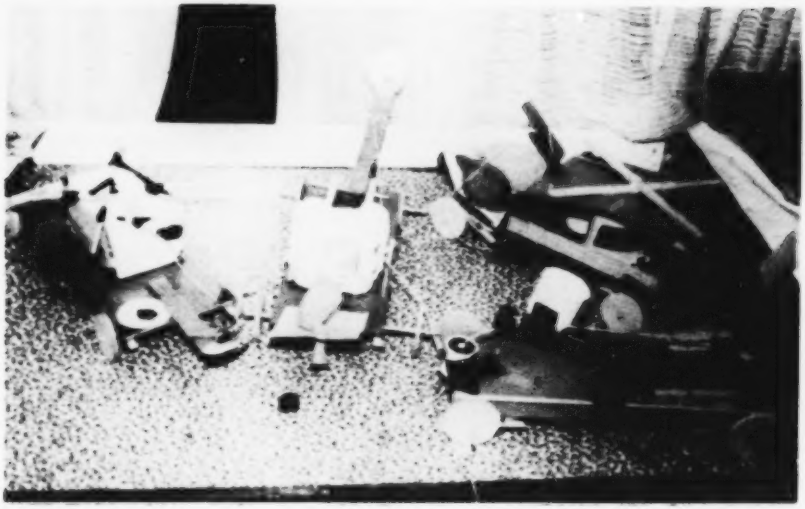
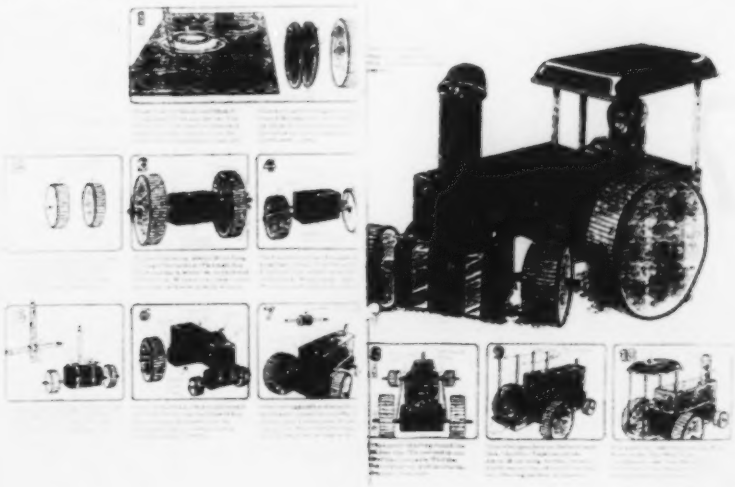


**Figure 4 Instructions to make a Traction Engine model**



Meanwhile, John (age 6 9) working alongside Ryan, used a lever system made of bent card, and a scoop also made of folded card, a simple string lift mechanism, and then became distracted by the challenge of making his model move by balloon power - in the end he needed help from the teacher to succeed. He finally added a set of helicopter blades to his digger!
The two girls working at the table appeared much less confident. They watched the two boys for some time before they began to make their diggers. Rebecca (age 6 8) frequently went to adults for reassurance, but in the end her model was very thoughtfully made. See Figure 2.

She used a pivot arm system, but with two side pieces joined at the top to strengthen the lifting device. She also used a system of two lengths of string pulling from opposite directions, fed through cotton reels stuck on either end of the chassis, to operate the scoop. In fact her yoghurt pot operated as a dumper rather than a digger. Diane (age 6 6) used a lever arm system and with a string mechanism threaded through a hole in the back of the chassis, but also made a cab with a seat for the driver.

The children demonstrated their models to the whole class and received a lot of positive feedback from the teacher and their peer group. See Figure 3 for all four models in their final versions.

**Exemplar 2**

Key Stage 2, Making a Model of a Traction Engine (Susan, Shelley, Ruth, all age 7)

The advisory team in this LEA encouraged teachers to emphasise more open-ended problem-solving approaches to teaching technology. They employed a design consortium to front their in-service provision for primary Technology. Teachers were encouraged to set up workshop areas with a range of material, tools and equipment permanently accessible where children were to work at their own pace and level. Sometimes activities were to be structured by the teacher, with a particular set of skills or a knowledge base (often linked to a current topic) to be acquired, but children were also to be encouraged to experiment and 'find things out for themselves' on self-chosen activities.

Three seven year old girls had come across instructions to make a small scale replica box model of a Titan Traction Engine with a steering mechanism made from string and sticks. The instructions were set out in a sequence of 10 annotated diagrams and related text. See Figure 4.

One of the girls told the researcher, 'I've been wanting to make it for ages 'cos it looked right good'. When they asked their teacher if they could make the model, she encouraged them, as a first stage of thinking the task through, to list the materials and equipment they needed. In a workshop area set up in a corner of the classroom, they assembled boxes, corrugated card, PVA glue, a glue stick, a large pair of scissors, pea-sticks, string and sellotape.

They began by casting around for containers to draw round to make 4 large and 4 small circles for the wheels. Following the diagrams in the instructions, they made tyres by cutting strips of corrugated card, measuring the length by eye, glueing them to the circles and chopping off any overlap. They completely missed a crucial strengthening device of cotton reel inserts for the wheels. See Figure 4.

Prompted by the sight of an eggbox and card tube in a container nearby, Susan turned her attention to another section of the instructions, scheduled for a much later stage in the model making according to the diagrammatic instructions, and began to make the smokestack, commenting as she worked 'Don't know what it's for. Might be for the smoke, but it's got that thing on top'.
Returning to the task that afternoon, the children were attracted by the novelty of using a block of wood for the main body of the engine. They took turns to struggle, without a bench hook or clamp, to saw the block to the 'right' size. A passing boy gave them authoritative instructions on how to mark the block with pencil before they began to saw. The girls stood passively and listened. Later they attached

the smokestack using a technique, learned from a sculptor (recently artist in residence in the school), of a set of card struts folded at angles of 90 degrees and glued to the body of the engine and the upright chimney. See Figure 5.

Their choice of the wooden block for the body of the engine caused a series of technical difficulties. The steering and axle mechanisms of the illustrated model involved making holes in the main body through which to feed the pea-sticks which were to provide a frame for the axle and steering mechanism. The Technology adviser in the LEA had recently circulated a document on safety in the use of hand tools. Policy forbade the use of a drill in school unless a drill-stand was available. In this school they were awaiting delivery of a stand. The children resorted to drilling holes with the sharp end of a large pair of scissors and a small screwdriver to make the hole through which to feed the stick! In the end, they attached the surface paraphernalia of a steering mechanism - a cotton reel and length of string attached to the front axle - but never got a steering system to operate. The field notes indicate that the girls had the knowledge to try to fix a working mechanism, but simply could not face the lengthy process of gouging a second hole lengthwise through the wooden block.

> 'Shelley, as the dominant member of the trio, persuaded the other two not to persevere with the working mechanism. It's a pity, because this could have been a useful learning experience. There was not much new technical knowledge applied to the task of making the model so far, whereas I doubt they have previous experiences of trying to make a steering mechanism'

The children's talk recorded as they worked confirms the researcher's view of what happened.

S Get me a garden stick and we'll snap it
M And we'll put it through and then it'll go round
S Wait. I know. Don't do it yet though.
M We need a hole.
S We don't 'cos I don't want to make it now. I'm just putting it on. I'm glueing it.
M Are you? But it won't go round then.
R The steering wheel won't work Shelley.
(All giggle)
S The steering wheel don't need to go round.
M Then we've made it!
S and R. No we haven't.

Next they turned their attention to the roof structure. They fixed a smart little card canopy, as illustrated in the instructions, with pea-sticks attached to the wooden block by copious lengths of sellotape. They coated the finished model with white emulsion paint - again a technique learned from the sculptor - and decorated it with powder paint using unsuitably large brushes.

In all the girls had spent sessions spread over five days on the model and were proud of it. 'We worked hard didn't we?' When asked about possible improvements, they acknowledged that they knew how they **could** have made the steering mechanism of the model work. 'We've got to put a pencil through there, but we can't be bothered. We can make a hole in it, but it takes too long'.

**FEATURES OF CAPABILITY**

There is no need to labour the point that the contextual variables implicit in these two exemplars - the support of an informed adult, the children's previous experiences of model making and mechanisms both at home and at school, the availability of appropriate tools and materials, access to information, the patterns of classroom organisation and styles of pedagogy in the schools - all these variables effected what the children achieved. However, there are certain features of capability which are critical

**Figure 5 The Traction Engine model in the making.**

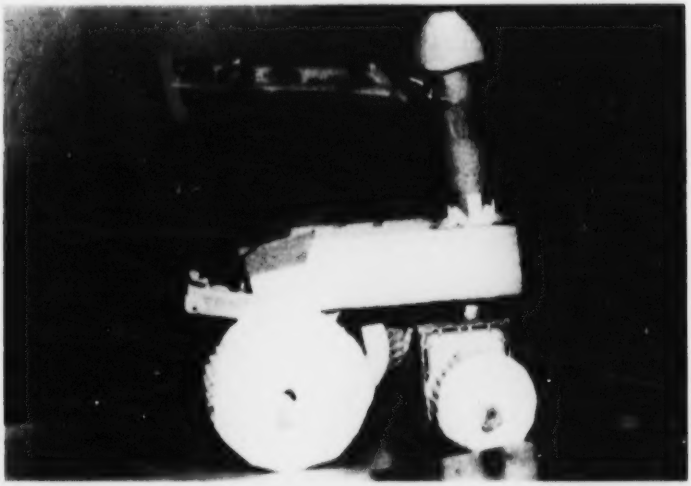


**Figure 6 Domains of design and technology capability at Key Stages 1 and 2**

Domains of design and technology capability at Key Stages 1 and 2

Identify needs and opportunities to generate a design

Plan and make

HOW

BY

WHAT

BY

Evaluate

if children are to make progress in achieving higher levels of capability in design and technology, though the likelihood of progression within them will always be dependent on the kind of contextual factors identified above.

Features of capability, categorised within three domains - Identifying Needs and Opportunities to Generate a Design, Planning and Making, and Evaluating - broadly relating to the four Attainment Targets of the current (at November 1993) NCC Technology Order (1990), are set out in Figure 6.

However, I want to discuss four features of capability that are generic to **any** model of technology education - communicating ideas through drawing, acquiring technical skills, acquiring technical knowledge, and evaluating.

**Communicating ideas through drawing**

From the first domain, attention is focussed on the feature of visualising and communicating emergent ideas in graphic form. The teachers we interviewed were aware of the possibilities of using drawing as a medium to express thinking, but were uncertain whether children were capable of matching their imaginative abilities with representational skills. One infant teacher said:

> 'I don't think they need to draw and plan at 5 years old. I think they want to make it first and possibly record and draw it afterwards. They don't know what it looks like before they've made it. To see it before you've done it, that's hard'

A junior teacher said:

> I encourage them to draw their designs before they make a model, but I have to admit that the designs that they make at the beginning, however fantastic they look, very often the end product isn't like that at all. The original drawing bears no relationship to what the children finally produce. I think what actually happens is that they are re-designing as they go along all the time, as they are making things. I think adults are the same. When they start making things up, often their original ideas are modified drastically, once they get working'

There are two issues to be distinguished here - one a cultural phenomenon and the other developmental. There is plenty of research evidence (Hall, 1987; Wells, 1987) to substantiate the claim that the acquisition of literacy skills is dependent on models of literacy behaviour surrounding the child at home and at school. In classrooms children will see reading and writing behaviours accorded high status, but drawing is not habitually demonstrated as a useful tool for organising or representing ideas. More usually, drawing is seen as a servicing agent for the 'real' work of writing stories - 'When you've finished your writing, draw your picture' - or for topic work - 'If you have any time left, copy a picture from the reference books of a Viking ship for the front of your project folder'. Teachers rarely demonstrate drawing skills to young children. In fact, modelling drawing behaviour is often vetoed by the primary school culture of encouraging children to be 'creative' as 'forcing children into an adult mode of representation'. I find this concept hard to reconcile with the accepted practice of teaching handwriting skills to young children.

A further culturally acquired assumption for young children is that making drawings in primary classrooms should be about aiming for a perfect end product. When the researcher asked two six year old boys who had been set the task of designing a hamster exercise area to 'scribble down a few ideas', they looked horrified. We should have recognised that in an infant classroom 'scribbling' is a taboo activity. Yet designers work from note-pad to materials, keyboard to screen, lines to words with an

Figure 7 Design drawing for a hamster exercise area.

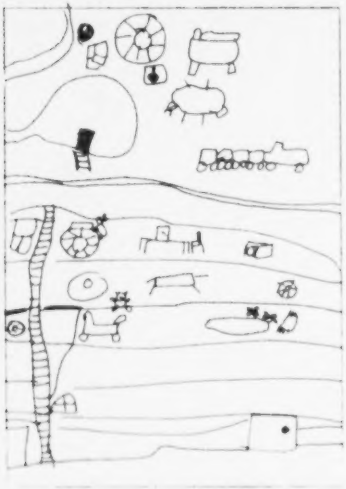


Figure 8 The completed prototype of the hamster exercise area

easy flow. Leonardo da Vinci's notebooks provide perfect evidence that thinking in words and lines can be mutually enhancing. But our education system rarely offers examples of adults modelling drawing as a tool for thinking.

On a huge piece of paper spread on the floor the two boys set to drawing an elaborate series of disconnected items for a happy hamster - a table and chairs, a bed with pillows and a duvet, packets of healthy (their word) cereals for breakfast, a jacuzzi, a pool for it to drink from, and a train set for it to play with. (See Figure 7)

Finally they began to enclose all these items in a cage-like structure in the drawing - horizontal bars representing the sides 'so that he can poke his little head out' and a door 'because he does need to go out for exercise'. When the researcher suggested that they might label some of the design elements - the beginnings of modelling an annotated drawing - she was firmly put in her place. 'We don't want to do that because we're not very good writers'. As the conversation ran on, it became increasingly clear that for these two children the design drawing was actually conceived as a gift for the hamster. They further justified their reluctance to write by, 'Anyway he's only a little baby hamster and he can't write yet.' It was clear that they were making no links at all between their drawing and its relationship to a proposed 3D model. In fact, towards the end of a long session of colouring in with felt tips, the dominant child said very firmly to the researcher, with eye contact fixed on his working partner, 'We don't **want** to make a model, do we?'

With skilfull intervention from the children's class teacher the following day, the boys **were** persuaded to tackle a prototype of the hamster exercise area. The teacher cued them into the task by asking them to tell her what materials they would need. They listed coloured paper - silver, gold and black (perhaps a concession to their image of a cage), coloured chalks (James had been waiting for the opportunity to get hold of these), a large box, wallpaper, string, pieces of carpet, wood, 'special paper to see through' (for windows'), a hole punch (for air holes), a Stanley knife (for the teacher to cut the window holes).

It was clear that at last the children were beginning to image with **materials** in mind. This brings us to a further dilemma for young children. They are rarely encouraged by teachers to apply their knowledge of materials and their properties at the stage when they are asked to do their initial design drawings. It is only through direct intervention from the teacher that the concept of drawing specific parts of a proposed model, defining in 2D exactly what materials are to be used to create the 3D outcome, is developed. No wonder, then, that the children's drawn designs bear so little relationship to their final models. Figure 8 shows how the hamster exercise area was finally made complete with tight rope, diving board, ladder and pool.

There is a further developmental aspect of our expectations of young children's capability in graphicacy. The development of children's competence in drawing has been studied extensively (Kellogg, 1979; Cox, 1991). We know that children struggle to master the graphical conventions of representing scale, spatial orientation and overlap. Expectations of what young children can reasonably be expected to represent in design drawing need to be re-assessed in the light of research evidence. Models of different styles of technical drawing need to be introduced to children along a broadly delineated developmental scale. It may be that the conventions of simple exploded diagrams and annoted drawings should be taught at Key Stage 2 before we expect children to tackle technical drawings at Key Stage 3. There is some evidence that very young children can cope with recording their model making in drawings **after** they have worked with materials (Gura 1991). This way round, at least the drawings of models are grounded in an understanding of the characteristics of the materials the children have used. Figures 9 and 10 represent a five-year old's attempts to record a lego model of a staircase.

Research by Banta (1980) suggests that it is at about nine years that children engaged in construction play tasks with building blocks can represent their design **intentions** in drawn form accurately. But

Figure 9 David's first attempt to represent his lego staircase.

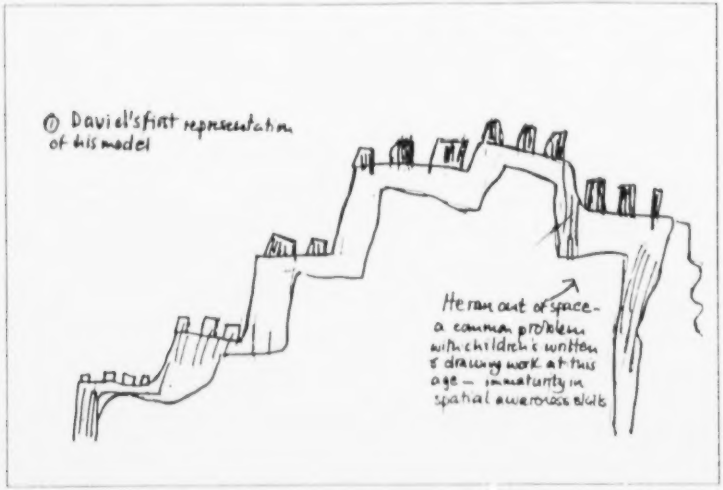
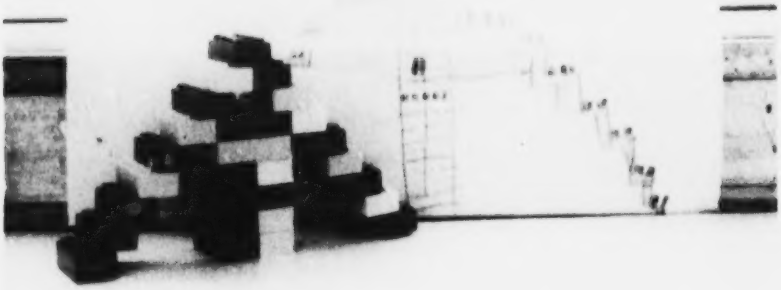

① David's first representation of his model
He ran out of space - a common problem with children's written & drawing work at this age - immaturity in spatial awareness skills

Figure 10 David's final drawing and lego model.



there is little empirical evidence to help teachers to structure a curriculum using drawing as a tool for thinking about making things, and in this research vacuum, children are being asked to use graphicacy in a way that would tax most adults

**Acquiring technical skills**

Other features to be discussed are within the second domain of capability in Figure 6 - Planning and Making - experimenting with materials and tools Our observations of children handling tools and equipment confirmed that the concerns the primary teachers had expressed to us in the interviews about their own ability both to model appropriate skills in cutting and joining hard materials and to manage the safety aspects of using cutting and drilling devices were well founded As one teacher said to us

> 'It's not only inflicting injuries on themselves or other people, but the furniture, tables and chairs and the floor you know You might find yourself ending up with a pile of firewood!'

In the exemplars two commonly observed dilemmas in children learning procedural knowledge, the 'knowing how' aspect of technological knowledge are illustrated The first one is a pedagogic concern In exemplar 1, the children **had** been given training by an advisory teacher in the handling of saws, using bench hooks, and drills, and using simple vices However, the teacher had not been given this training She was therefore unable to support the children by correcting inappropriate behaviours when they moved from the closely supervised practice tasks overseen by the advisory teacher to the capability task of making a model of a building site machine It is perhaps also worth reporting that the practice task left the children profoundly bored The teacher had an embarrassing moment or two 'persuading' the children to go back for a further dose of direct instruction from the well-intentioned advisory teacher after the morning break!
In exemplar 2, the children were forced by circumstances to work with inappropriate tools Highly motivated by the challenge of a self-directed task, they persevered for several hours in order to make a hole through a piece of wood that could have been achieved in minutes with appropriate tools and adult guidance This may have been an exercise in character building, but it was hardly developing technology capability

One of the primary teachers we worked with was clear about the need to give direct instruction in technical skills

> 'There's a school of thought that sort of says to the kid 'You've got to find out' But it's very frustrating for a child thinking how the hell do I join these two pieces of wood together without it falling apart when I want to make something By not interacting with them and saying 'Look, this is how you do it This is how you use a saw and this particular tool you are using is for this particular function' Because that's how people use tools They don't use a great big saw when they need to use a small one There's got to be some formal input in some ways - how we use tools, how we use materials, what materials are good with other materials - that type of thing'

The second concern is developmental We observed children handling brand new and expensive tools - displayed proudly in design and technology workshop areas - with great difficulty Saws and hand-drills caused particular concern Children were struggling to master the gripping, positioning and moving of hands on a range of types of tools - some with pistol grips, some with indented handles, some large, some small, some rigid, some flexible We saw simple tools like scissors and brushes being incorrectly handled We saw left handers being left to struggle with equipment designed for right handers What seems lacking is research evidence about the development of children's fine motor control and hand/eye co-ordination in classrooms and the application of that knowledge to the design of school equipment and to teaching strategies to encourage progression in practical work What is also lacking is the study of the physical development of young children in primary initial training

programmes. It has been lost in the shift away from Child Development courses towards courses focussed on curriculum, pedagogic and po' cy concerns.

**Acquiring technical knowledge**

The acquisition of technical knowledge, the 'knowing that' aspect of technological knowledge, is embedded in two features in column 2 of Figure 6 - seeking out information specific to the task from books, photos, diagrams etc. and asking questions/seeking advice.

In the exemplars children were clearly drawing on technical knowledge acquired from previous experiences. The children making the diggers lived in a rural setting where large agricultural machinery was part of their daily lives. They had absorbed a lot of information about leverage and joints. The teacher had also resourced the children's modelling through a class discussion, a set of picture books with diagrams and photographs of machines, and was planning a visit to a building site. The quality of the children's problem-solving strategies bears witness to the quality of teaching and resource preparation that preceded the task. Without a grounding in conceptual understanding, the children would not have been so capable in constructing lifting arms for the diggers. But Rebecca constructed a dumper rather than a digger. It seemed difficult for her to grasp the concept of which direction her scoop was to face whilst working with the double system of string pulls she was using and there was no informed adult on hand to help her resolve this problem. Ryan also needed more technical knowledge to complete a winding mechanism for his string pull. He too would have benefited from the presence of a knowledgeable adult to help him to acquire the new understanding he needed - either by practical demonstration or by reference to diagrams or photographs. John was anxious to experiment with pneumatics - clearly referencing back to previous learning - by equipping his digger to move by balloon power, and the helicopter wings he added as the final touch were pure flights of fantasy!

In exemplar 2, the three girls achieved the satisfaction of completing a **representation** of a traction engine - aesthetically pleasing in its final version - but they did not learn how to make a model with a functioning steering mechanism as specified in the diagrammatic instructions they were following. It seemed a wasted opportunity. It is significant that when a small group of boys, inspired by the girls' model, set out to make their version of a traction engine, they were far more interested in the working components. They brought to the task knowledge from working with lego and meccano vehicles and from observing fathers, brothers and uncles making models. We found that girls were not often pushed by teachers to persevere in acquiring technical knowledge, and because the role model was absent from their lives outside school, they were content to stay at a basic level of competence in mechanical engineering. In this exemplar, the girls were capable of following sequential diagrammatic instructions - a skill in its own right and one they had practised in cooking sessions - but were not pressed to really work technical details. Thus the teacher was inadvertently colluding in their resistance to acquiring new technical knowledge. Ironically the freedom of the workshop mode of organisation in what would seem 'ideal'learning conditions, where children were working with high levels of motivation and self chosen tasks, mitigated against higher level of achievement.

**Evaluating**

The teachers with whom we worked found the prospect of getting children to evaluate their work unrealistic. As one teacher pointed out:

> 'We ask the child when they've finished a model or a piece of work, are you pleased with it, or would you like to change it, but they usually say, 'Well, I like it as it is'.'

However sensitively asked, the teacher's questions, because of the inbuilt imbalance in the power relationship between teacher and taught, seemed to imply criticism. Children naturally reacted



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defensively to this Worse still, if the child admitted that a piece of work might be improved, they knew that the teacher might ask them to do it again! Evaluation conceived as a bolt on process simply did not work Many children were genuinely puzzled at the idea of having to 'improve' something on which they had worked very hard

I suspect that a further issue is that children simply do not have a range of mental models against which to make informed judgements about improving a product There is a parallel dilemma in writing lessons Teachers struggling to get children to redraft writing meet exactly the same resistance Moreover, children lack the vocabulary to evaluate effectively 'I like it because it's red' are the kind of responses young children make

A comment from an experienced teacher of technology summed this all up

> 'I find mine unwilling to change, modify designs Even is something was falling apart, they'd be happy with it But it all depends on how you treat them, because the next time they would do it differently At a later date what has gone wrong has penetrated and they do realise and do it differently next time But I don't think it's fair to ask them at that age to re-do it I think you can put them off '

The concept of 'evaluation' as 'doing it again' reveals a common misunderstanding Far more productive, the teachers were beginning to discover, was for evaluation to permeate the whole iterative cycle of designing and making Hence in Figure 6 the domain of evaluation runs across all other domains It was particularly productive to pair children to talk to each other about the changes they might make in their products The decisions were fed back at whole class or group discussion times In this way the knowledge, vocabulary and attitudes to improve evaluation skills were built up over a long period of time through exchanges with peer group at about the same level of competence in design and technology
It would be interesting to look across curriculum areas to investigate whether this reluctance to make changes is a generic and developmental stage in, for example, writing, drawing, and model making - or whether the ability to evaluate is simply a question of modelling and teaching the skills and techniques of evaluation to young children in the context of teaching a particular aspect of the curriculum Again it is an aspect of young children's learning in need of research

## IMPLICATIONS FOR THE TEACHING OF TECHNOLOGICAL CAPABILITY

Technology was a new subject for primary schools in 1990 With no trainers at Inservice or Initial Teacher Training levels with experience of teaching Technology at Key stages 1 and 2, teachers have been left to operationalise the Order through trial and error It is remarkable how much they have achieved in five years Only now are government agencies commissioning support materials (SCAA, 1993(a), 1993(b)) In operationalising the Order primary teachers have had to confront squarely some 'hidden' dilemmas about the status and state of practical work

From the features of capability discussed in this paper the following issues about teaching technological capability are highlighted

### 1. Communicating through drawing

If children are to be asked to use drawing as an aid to imagining and describing emergent ideas, teachers need a clear understanding of how children's drawing capability develops Teachers would then have more realistic expectations of when and how drawing can best be used to enhance children's designerly thinking

In order for children to make progress in drawing, teachers need to provide examples in the classroom of how designers and artists use drawing as a tool for thinking. Teachers themselves need to have a sense of the purposes of various types of drawing - e.g. observational and annotated drawing, exploded and sequenced diagrams - and convey these purposes to pupils when setting tasks and giving feedback whilst work is in progress.

Teachers need to encourage children to think about the function and characteristics of materials appropriate to the products and outcomes as they imagine and to make realistic plans and draw designs with these materials in mind.

**Acquiring technical skills**

Most primary teachers are 'practical' people, often versatile and skilful in the use of art and craft tools and equipment. As a predominantly female work force they often lack experience in handling tools and equipment for cutting and fixing hard materials. It may be possible for them to learn these skills by enlisting the help of skilled craftworkers in their local communities and so gain the expertise and confidence they need to teach their pupils how to handle tools safely and how to use their strength and energy most effectively to saw, drill, chisel and hammer etc.

On a more general level teachers need to examine the gaps between their claim to value practical, experiential learning and the reality of how little attention they habitually pay to teaching 'practical intelligence'. The well established pedagogical routines of using practical work as 'holding' activities in primary classrooms needs reassessing. Teachers have to acknowledge that procedural knowledge, the 'knowing how', is not simply acquired by 'learning through doing'. Only when teachers pay sustained attention to children's learning on making and doing tasks, will they develop a clearer understanding of how children improve fine motor skills and what role teachers can most effectively play in ensuring that children do make progress.

**3. Acquiring technical knowledge**

Gaps in primary teachers technical knowledge have been identified in studies of qualified and trainee teachers (reported in Kruger et al, 1990). Resource material is beginning to come on to the market both to support teachers' own knowledge base and to encourage them to set up sequences of 'resource' tasks for children designed to develop understanding of key concepts (e.g. levers, pulleys, energy, structures). 'Resource' tasks are designed to build up a knowledge base that will be used in a 'capability' task. For example, a series of activities designed to teach children how to make moving joints might lead to designing and making puppets for a performance.

The notion that children are best taught technical knowledge, 'the knowing what', at the point of needing to apply it may be attractive, but only feasible if an adult is working with a child on a one-to-one basis (for example as a parent at home or in a diagnostic teaching session as a teacher). Technology teachers need to plan with colleagues in anticipation of what knowledge base within the Order is statutory for each Key stage. Alongside sequences of structured tasks, children should also have opportunities to experiment with mechanisms, structures, materials, fixing devices etc. on tasks of their own choice.

Teachers need to plan, as they now do for English or Science, for a mixture of class, group and individualised learning activities. Some teachers are designating days when they give sustained quality teaching time to a group doing technology. Others are setting up Technology Days when the whole class focus will be a variety of different but related activities, when the teacher can devote his/her time exclusively to teaching, monitoring and supporting children's learning in technology.

**4. Evaluating**

Teachers are encouraged to plan for opportunities for children to evaluate a selection of 'real' artefacts - sports bags, scisssors, packaging. Children are introduced to the idea of comparing a range of items against a set of criteria and they learn the vocabulary of evaluation. Thus an evaluation process and associated language are modelled for children.

When these skills are transferred to their own work, it is important to retain an iterative cycle of evaluating and refining products as children work, rather than using evaluation as a 'bolt-on' exercise.

**CONCLUSION**

As the revised Order is introduced into primary schools in 1995, it will be essential for teachers to have a better understanding of teaching and learning technology if children's design and technology capability is to be further enhanced.

There are so many features of design and technology capability that are under-researched. These four specific features are being investigated during a second phase of research into capability in technology in primary schools based at the School of Education at the University of Leeds starting in January 1993.

Further information from Angela Anning

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Further information about the activities of the Group may be obtained from A. Anning, School of Education, University of Leeds, Leeds LS2 9JT,U.K.

The following Occasional Publications of the Groups are available.

No.1 Peter Medway, *Technology Education and its Bearing on English*,1990 (£1)

No.2 Peter Tomlinson, *The Flexible Learning Framework and Current Educational Theory*, 1992 (£2)

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